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Reactance and Resistance in Series

By the Engineering Department, Aerovox Corporation

AS a companion to the chart of the January 1936 issue of the Research Worker we present in this issue a chart and table for the finding of the impedance of series circuits consisting of resistance and reactance. Although the vector addition of R and X is not very difficult when the two are in series it is often awkward and the chart should help to solve such problems at a glance.

The impedance, Z, of a combination resistance, R, and a reactance, X, in series is given by the equation

$$Z = \sqrt{R^2 + X^2}$$

When Z is given and either X or R is the unknown, this equation can be re-written:

$$R = \sqrt{Z^2 - X^2}$$

$$X = \sqrt{Z^2 - R^2}$$

In all these equations all three quantities are expressed in ohms and X can be either capacitive reactance (1/6.28 fC) or inductive reactance (6.28 fL).

The equation suggests immediately that the three quantities can be accurately represented by the three sides of a right triangle where R and X represent the rectangular sides and Z the hypothenuse. So, it follows that anyone could draw such a triangle to scale, thus avoiding any struggle with square roots. A chart could be made up on ordinary cross-section paper, drawing circles on it for various values of Z while the ordinary coordinates would represent X and R. Such a chart is rather hard to read and it has the severe drawback that it uses linear scales so that it becomes impossible to cover a large range. Therefore it was felt best to resort again to the logarithmic scales even if the curves then become somewhat more involved. The chart has also been prepared in a way to facilitate its use when the reactance is not known but either f and C or f and L are given.

Referring now to the chart on the third page of this issue, resistance is measured along the vertical axis (the paper is supposed to be turned with the long side horizontal). Reactance is measured along the abscissa, the horizontal axis. Due to mechanical requirements the figures for these scales had to be placed above and to the left of the chart so as not to interfere with the figures referring to the curves. Taking any value of reactance and resistance follow the horizontal and vertical coordinates until they intersect and find the impedance of the two in series. In general the point will not fall exactly on one of the curves representing a round value of Z but the difference may be estimated.

Above the X scale are two others, marked fL and fC. These give the values of the products named, for each value of X. The reactance of a 1 mfd. condenser at 100 cycles (fL = 100) is 1,600 ohms, so the point fL = 100 is in line with the 1,600 ohm division on the X scale. This same point also refers to a condenser of .1 mfd. at 1,000 cycles, .01 mfd. at 10,000 cycles, etc. The same reasoning holds for the fL scale.

The use of the chart is best illustrated by an example:

The choke in a power pack has an inductance of 15 henries and a resistance of 500 ohms. What is the impedance at 120 cycles? Here the product fL is 120 x 15 or 1,800. Locate 1,800 on the fL scale and follow the line downwards until it intersects the horizontal line representing R = 500 ohms. This point lies between the two lines Z = 10,000 & Z = 20,000. By estimation we find Z = 11,500 ohms approximately. Note that in this particular problem it would make very little difference if R was slightly more or less; the answer would have been the same. This will be found the case when one of the quantities R or X is very much larger than the other; Z will always be found to be nearly equal to the larger one of the two.

Consider a tone control consisting of a .05 mfd. condenser and a 50,000 ohm variable resistor. When the resistance is all in the circuit, what is the impedance at 100 cycles, 1,000 cycles, 10,000 cycles? How are these relations when the series resistance is only 1,000 ohms?

First take a series resistance of 50,000 ohms, C = .05 mfd. and f = 100 cycles. Then fC equals 5. On the chart find the intersection of the lines fC = 5 and R = 50,000. This point is beyond the limits of the chart so we find the intersection between the lines fC = 50 and R = 5,000. The answer will be found to be Z = 5,900, it must be multiplied by 10 since we divided the reactance and resistance by 10 in order to bring it within the borders of the chart. So the impedance of the tone control at 100 cycles is 59,000 ohms.

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Considering a higher frequency, note that Z decreases rather slowly with the increase of frequency and that Z never becomes lower than 50,000 ohms.

When R equals 1,000 ohms, and fC is 5, the chart shows that Z equals 314,000 ohms approx. But at 1,000 cycles (f = 50) Z is approximately 3,200 ohms while at 10,000 cycles Z is only slightly above 1,000 ohms. This illustrates the tone control effect of such a series combination.

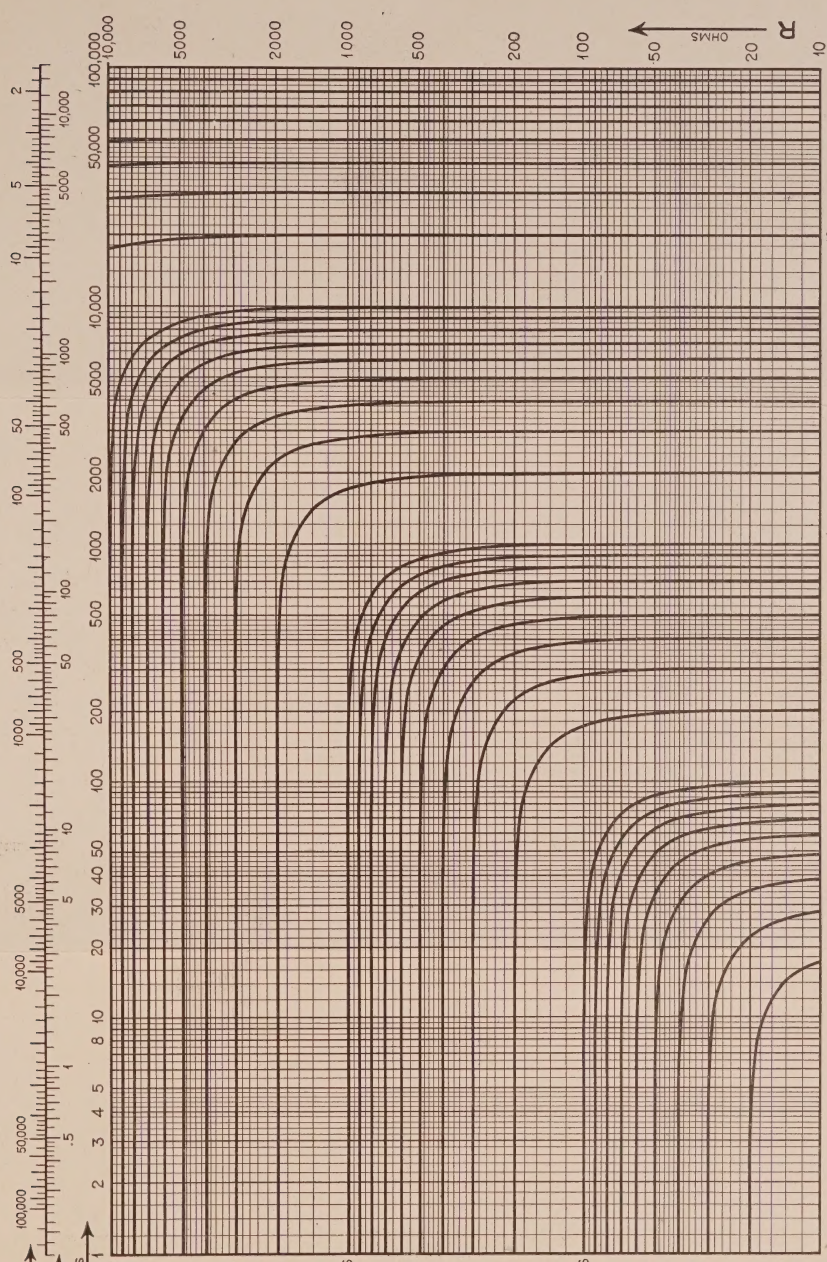
THE TABLE

For those who wish a greater accuracy, a table has been figured out. This table gives the values of all three quantities for the case that either X or Z is equal to 1. In other cases, find the ratio R/X or X/R refer to the table and find the corresponding ratio Z/X or Z/R. The table can also be used when Z is given together with one of the other quantities. It was for this reason that the table had to be extended for values of R/X or X/R from .1 to 10 since otherwise it would have been sufficient to include values from 1 upwards or downwards but not both. Example: suppose X = 1,600 ohms and R = 1,000 ohms. Then X/R = 1.6; the table shows Z/R = 1.8868. Then Z equals 1.8868 times R or 1886.8 ohms.

Both the chart and the table show clearly that where X is much larger than R or vice versa, Z is equal to the largest so further extension of the table is unnecessary.

TABLE OF REACTANCE AND RESISTANCE VALUES IN SERIES

X/R or R/X	Z/R or Z/X	X/R or R/X	Z/R or Z/X	X/R or R/X	Z/R or Z/X
0.10	1.0050	0.70	1.2207	4.1	4.2202
0.11	1.0060	0.71	1.2264	4.2	4.3174
0.12	1.0072	0.72	1.2322	4.3	4.4147
0.13	1.0084	0.73	1.2381	4.4	4.5122
0.14	1.0097	0.74	1.2440	4.5	4.6098
0.15	1.0112	0.75	1.2500	4.6	4.7074
0.16	1.0127	0.76	1.2560	4.7	4.8052
0.17	1.0144	0.77	1.2621	4.8	4.9030
0.18	1.0161	0.78	1.2682	4.9	5.0009
0.19	1.0179	0.79	1.2744	5.0	5.0990
0.20	1.0198	0.80	1.2806	5.1	5.1971
0.21	1.0218	0.81	1.2869	5.2	5.2952
0.22	1.0239	0.82	1.2932	5.3	5.3935
0.23	1.0261	0.83	1.2996	5.4	5.4918
0.24	1.0284	0.84	1.3060	5.5	5.5901
0.25	1.0308	0.85	1.3125	5.6	5.6885
0.26	1.0333	0.86	1.3190	5.7	5.7871
0.27	1.0358	0.87	1.3255	5.8	5.8856
0.28	1.0384	0.88	1.3321	5.9	5.9841
0.29	1.0412	0.89	1.3387	6.0	6.0828
0.30	1.0440	0.90	1.3454	6.1	6.1814
0.31	1.0469	0.91	1.3521	6.2	6.2801
0.32	1.0499	0.92	1.3588	6.3	6.3789
0.33	1.0530	0.93	1.3656	6.4	6.4777
0.34	1.0562	0.94	1.3724	6.5	6.5764
0.35	1.0595	0.95	1.3793	6.6	6.6752
0.36	1.0628	0.96	1.3862	6.7	6.7741
0.37	1.0662	0.97	1.3932	6.8	6.8731
0.38	1.0698	0.98	1.4001	6.9	6.9720
0.39	1.0733	0.99	1.4071	7.0	7.0711
0.40	1.0770	1.00	1.4141	7.1	7.1701
0.41	1.0808	1.1	1.4866	7.2	7.2691
0.42	1.0846	1.2	1.5621	7.3	7.3681
0.43	1.0885	1.3	1.6401	7.4	7.4671
0.44	1.0925	1.4	1.7205	7.5	7.5662
0.45	1.0966	1.5	1.8028	7.6	7.6654
0.46	1.1007	1.6	1.8868	7.7	7.7646
0.47	1.1049	1.7	1.9723	7.8	7.8638
0.48	1.1092	1.8	2.0591	7.9	7.9630
0.49	1.1136	1.9	2.1471	8.0	8.0623
0.50	1.1180	2.0	2.2361	8.1	8.1615
0.51	1.1225	2.1	2.3259	8.2	8.2608
0.52	1.1271	2.2	2.4166	8.3	8.3600
0.53	1.1318	2.3	2.5080	8.4	8.4594
0.54	1.1365	2.4	2.6000	8.5	8.5580
0.55	1.1413	2.5	2.6926	8.6	8.6576
0.56	1.1461	2.6	2.7857	8.7	8.7572
0.57	1.1510	2.7	2.8792	8.8	8.8566
0.58	1.1560	2.8	2.9732	8.9	8.9560
0.59	1.1611	2.9	3.0676	9.0	9.0554
0.60	1.1662	3.0	3.1623	9.1	9.1548
0.61	1.1714	3.1	3.2573	9.2	9.2542
0.62	1.1765	3.2	3.3526	9.3	9.3536
0.63	1.1819	3.3	3.4482	9.4	9.4530
0.64	1.1873	3.4	3.5440	9.5	9.5524
0.65	1.1927	3.5	3.6400	9.6	9.6518
0.66	1.1981	3.6	3.7362	9.7	9.7512
0.67	1.2037	3.7	3.8327	9.8	9.8507
0.68	1.2093	3.8	3.9293	9.9	9.9503
0.69	1.2149	3.9	4.0262	10.0	10.0499
		4.0	4.1231		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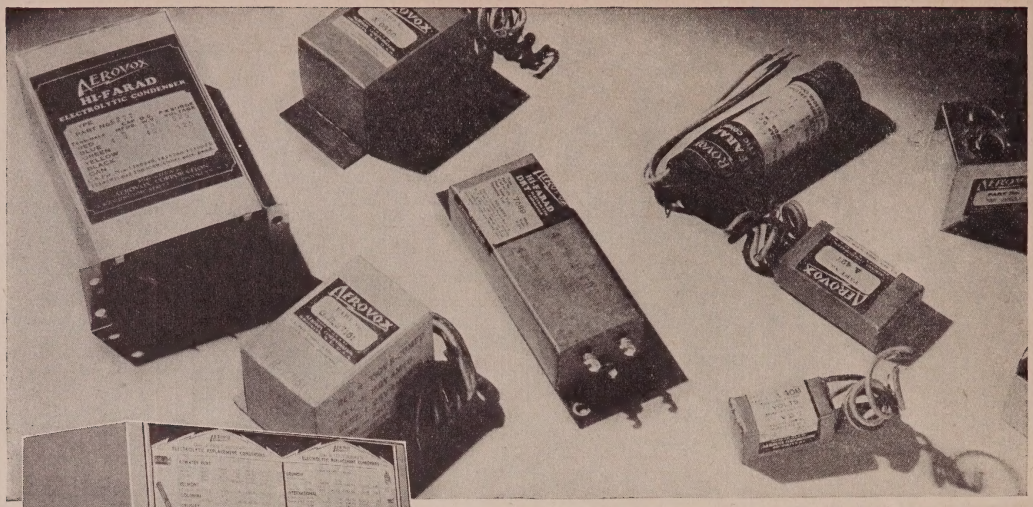

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